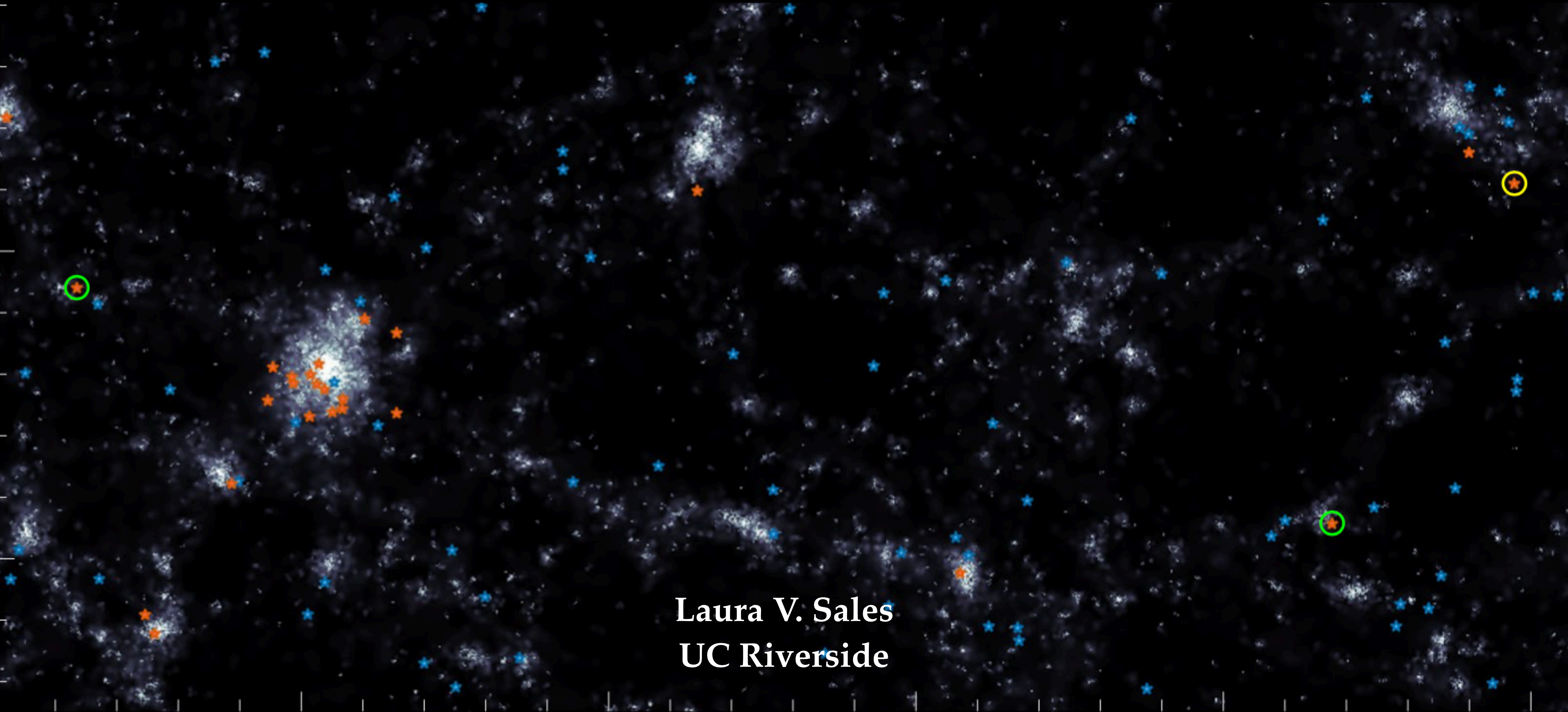
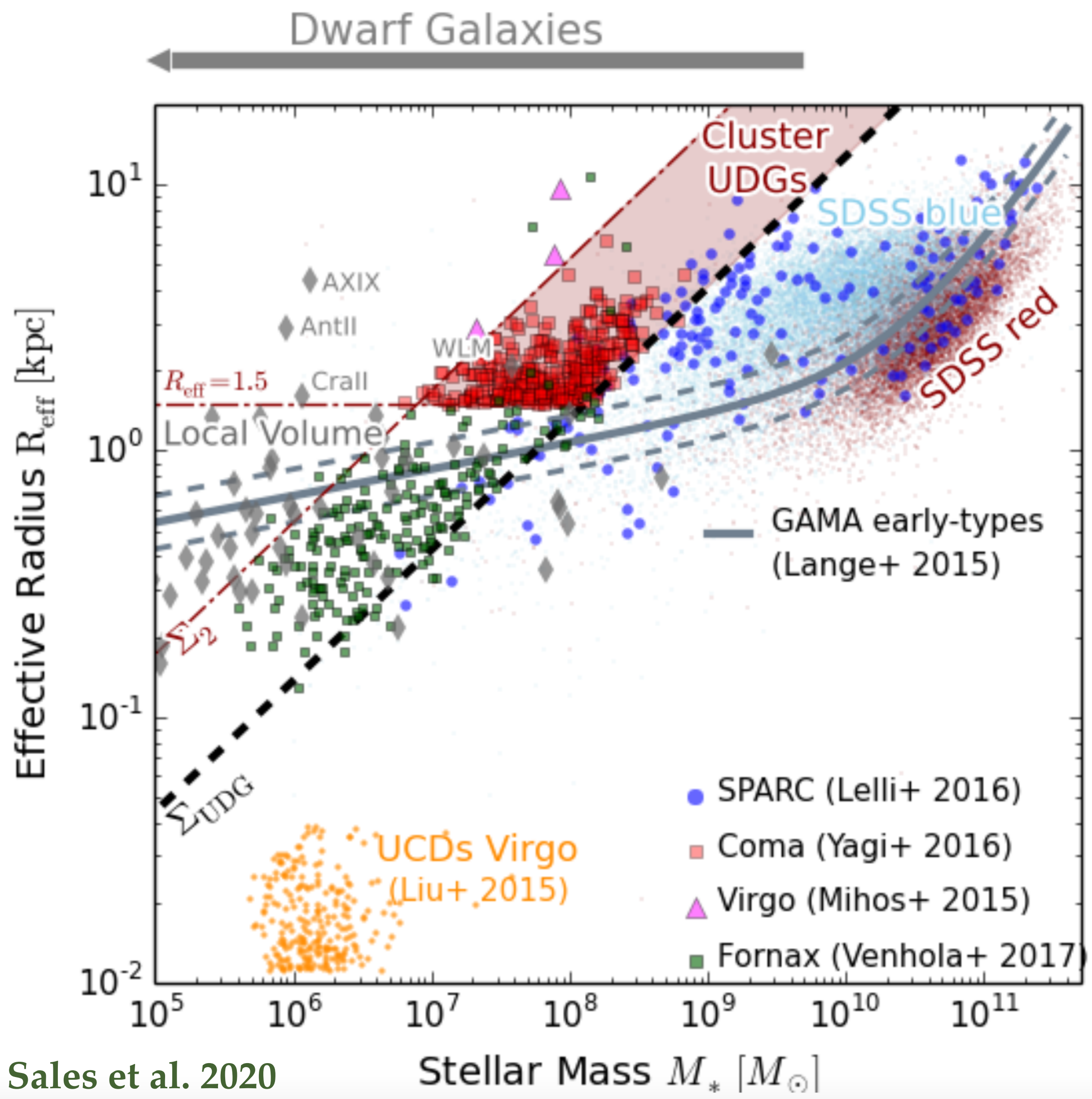


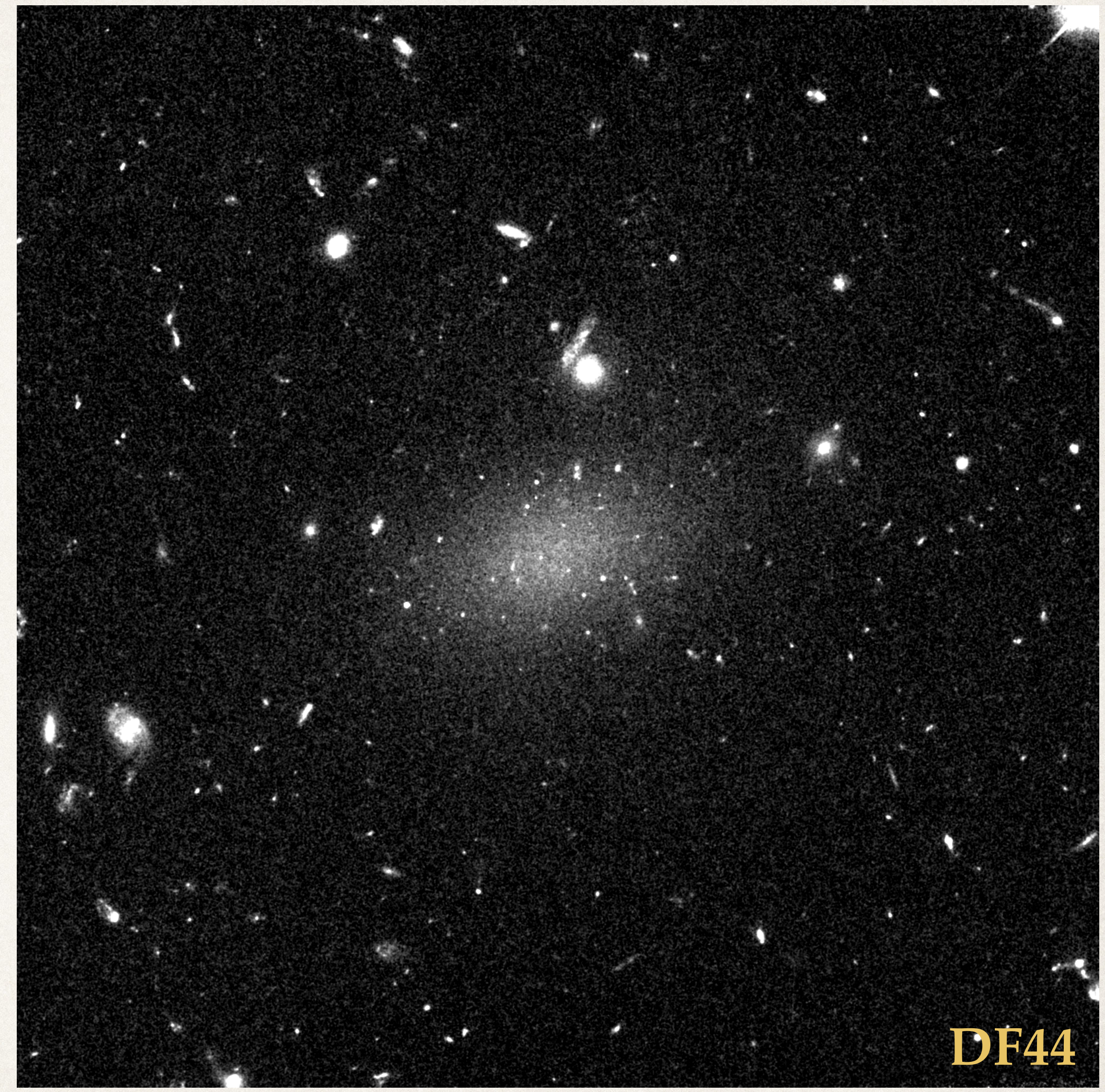
The formation and dark matter content of ultra-diffuse galaxies



Laura V. Sales
UC Riverside



Sales et al. 2020

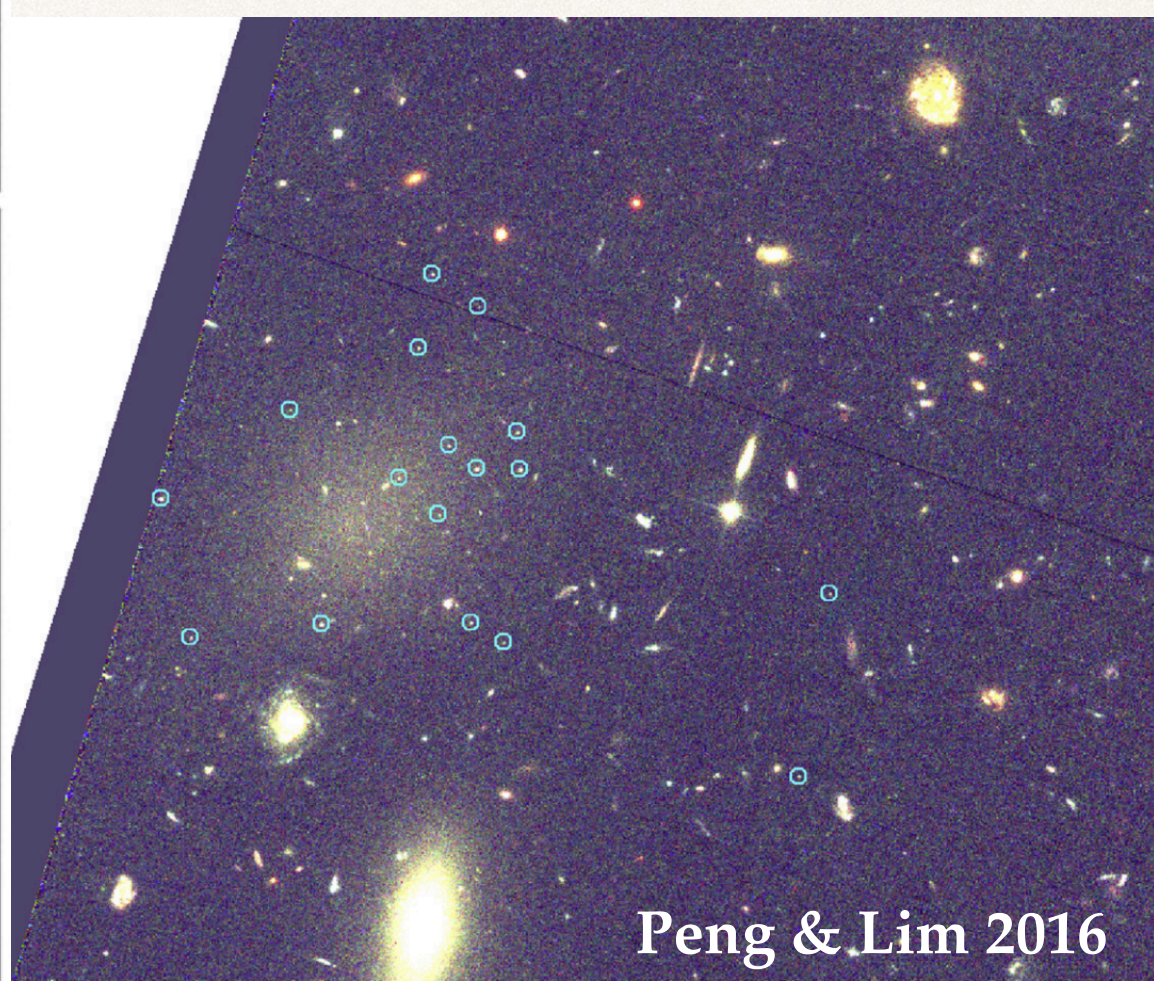
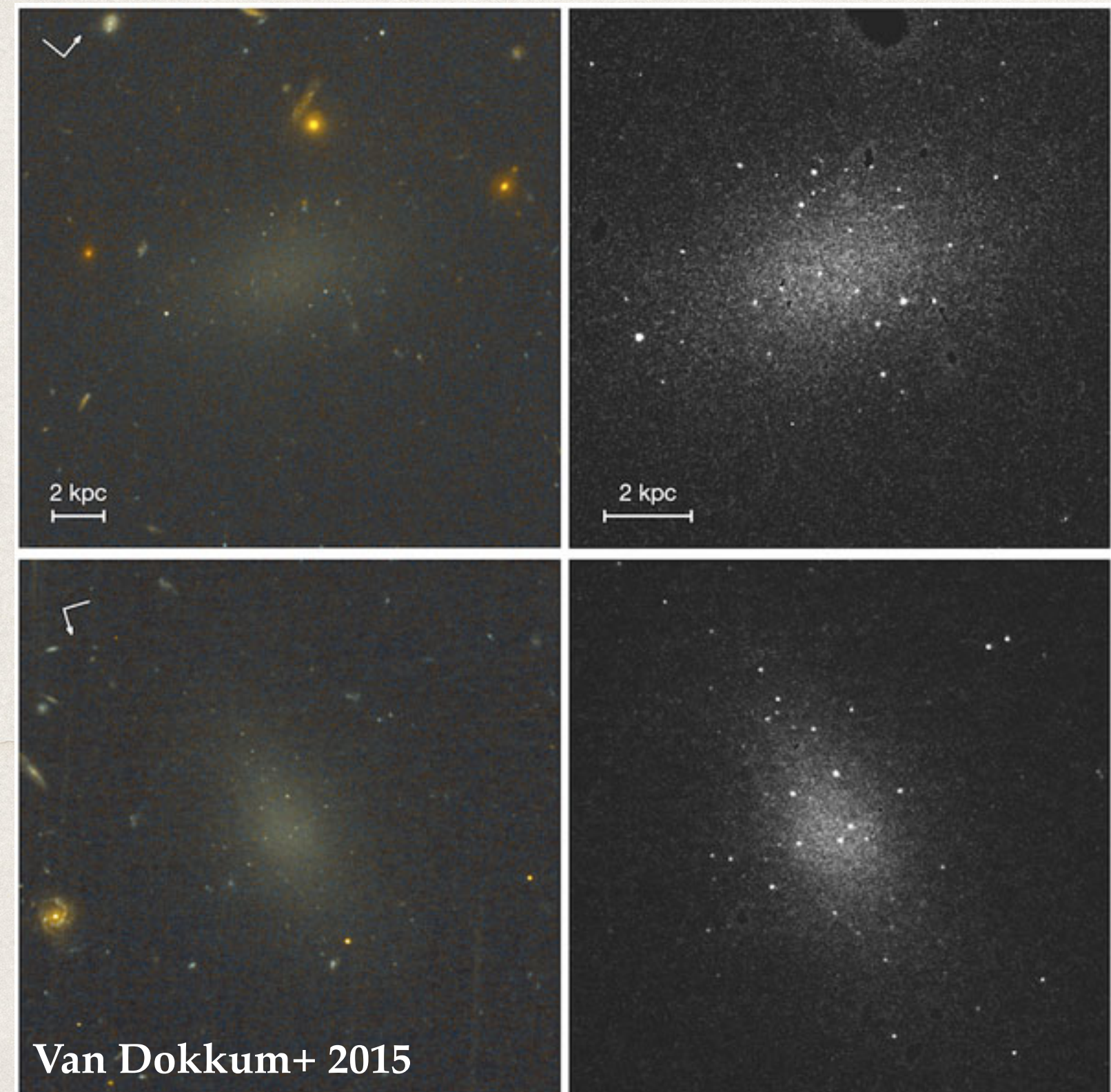


DF44

van Dokkum et al. 2015

Formation mechanisms of UDGs?

**Failed MW-like galaxies
vs.
dwarf halos**



internal

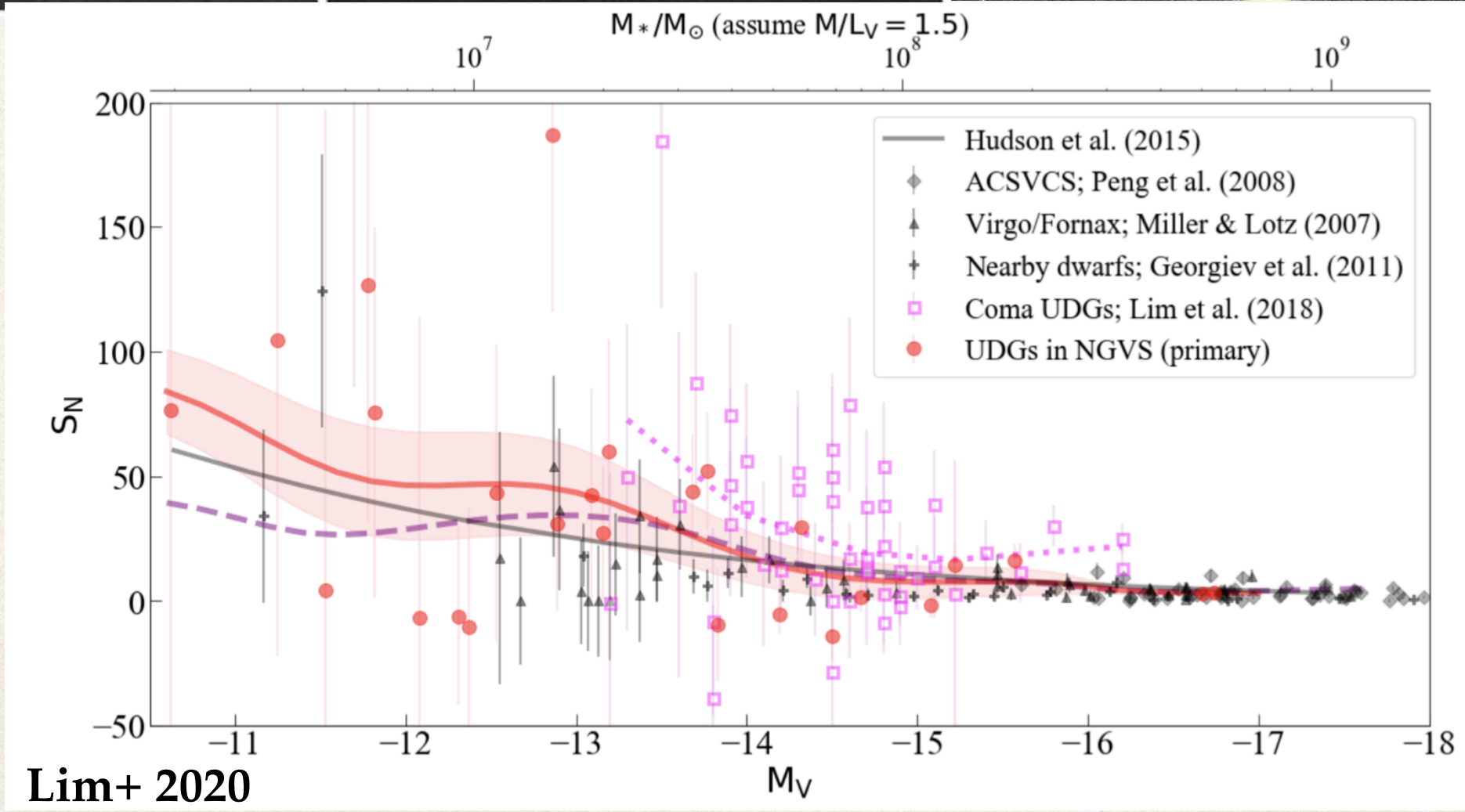
external

mix

- High spin halos**
Amorisco & Loeb 2016
- Feedback-driven expansion**
Di Cintio et al. 2017, Chan et al. 2018
- Mergers**
Wright et al. 2021

- Tidal heating (expansion)**
Safarzadeh & Scannapieco 2017, Roman & Trujillo 2017
- Ram pressure + quenching**
Tremmel et al. 2020
- Tidal disruption in cored halos**
Carleton et al. 2019

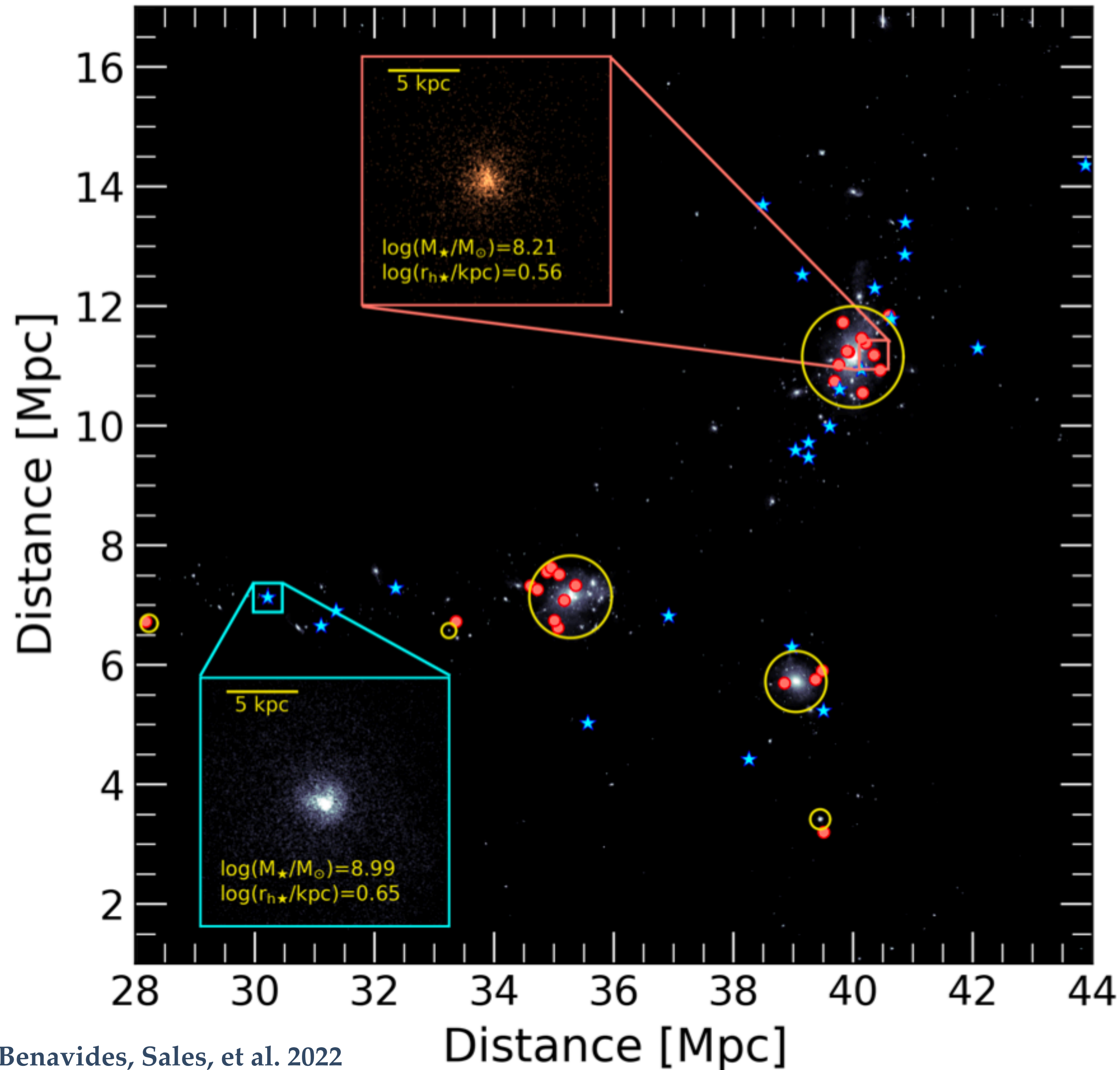
- Combination of internal + external**
Jiang et al. 2019, Sales et al. 2020



Lim+ 2020



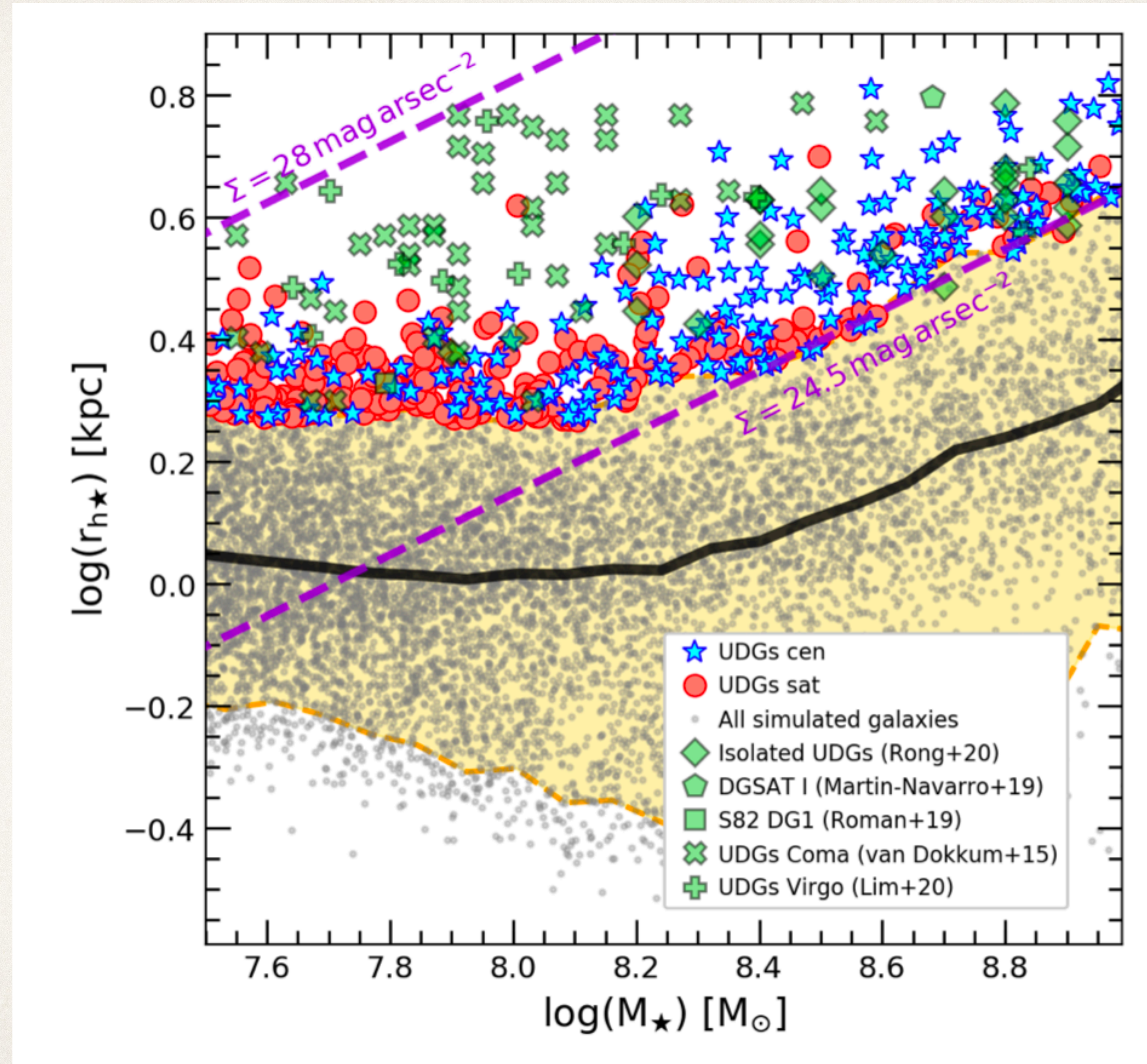
Jose Benavides
(postdoc UCR)



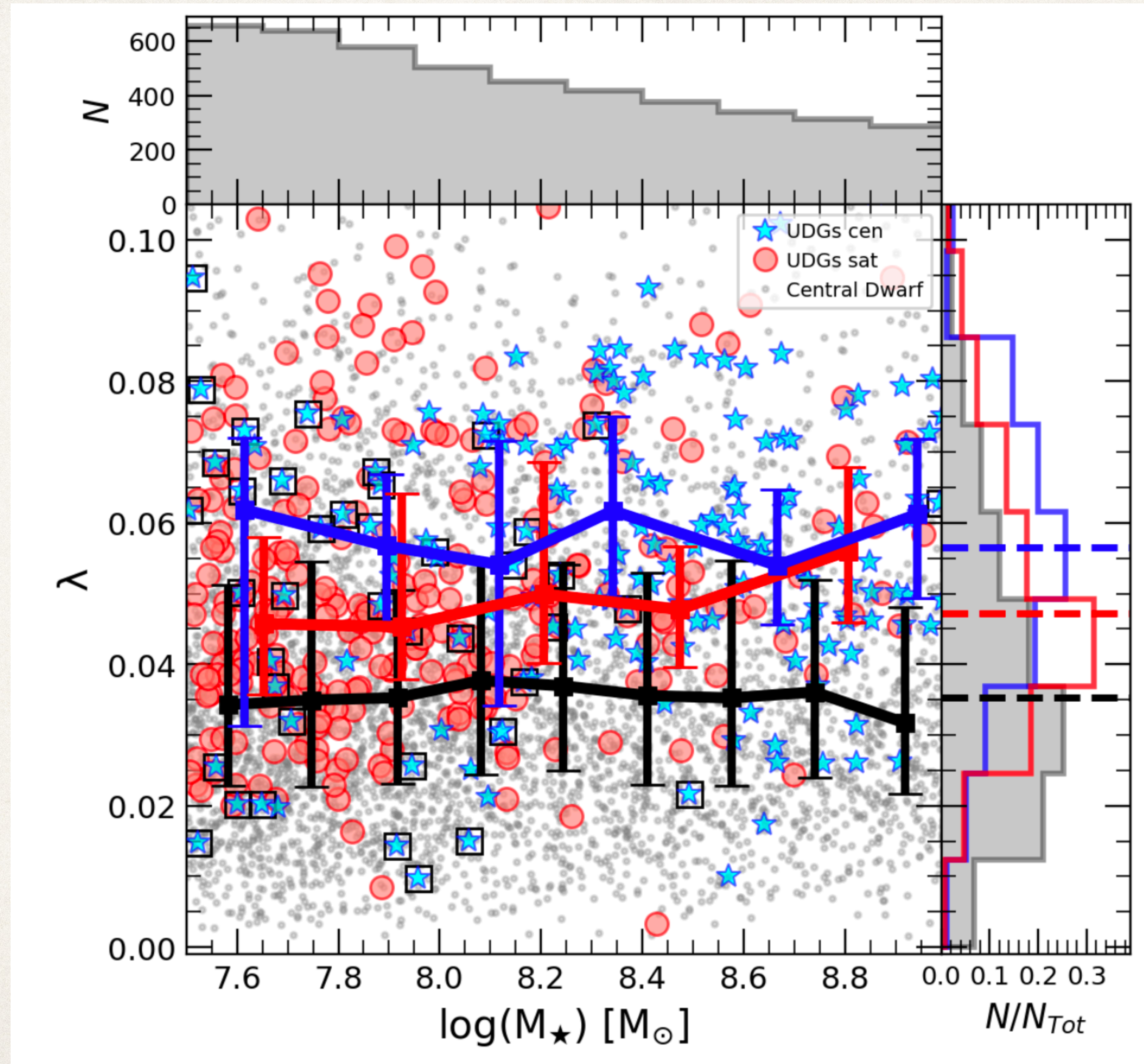
The TNG50 box offers the unique opportunity to study UDGs in different environments with a uniform resolution and baryonic treatment.

UDGs definition

Most extended 5% at a given stellar mass



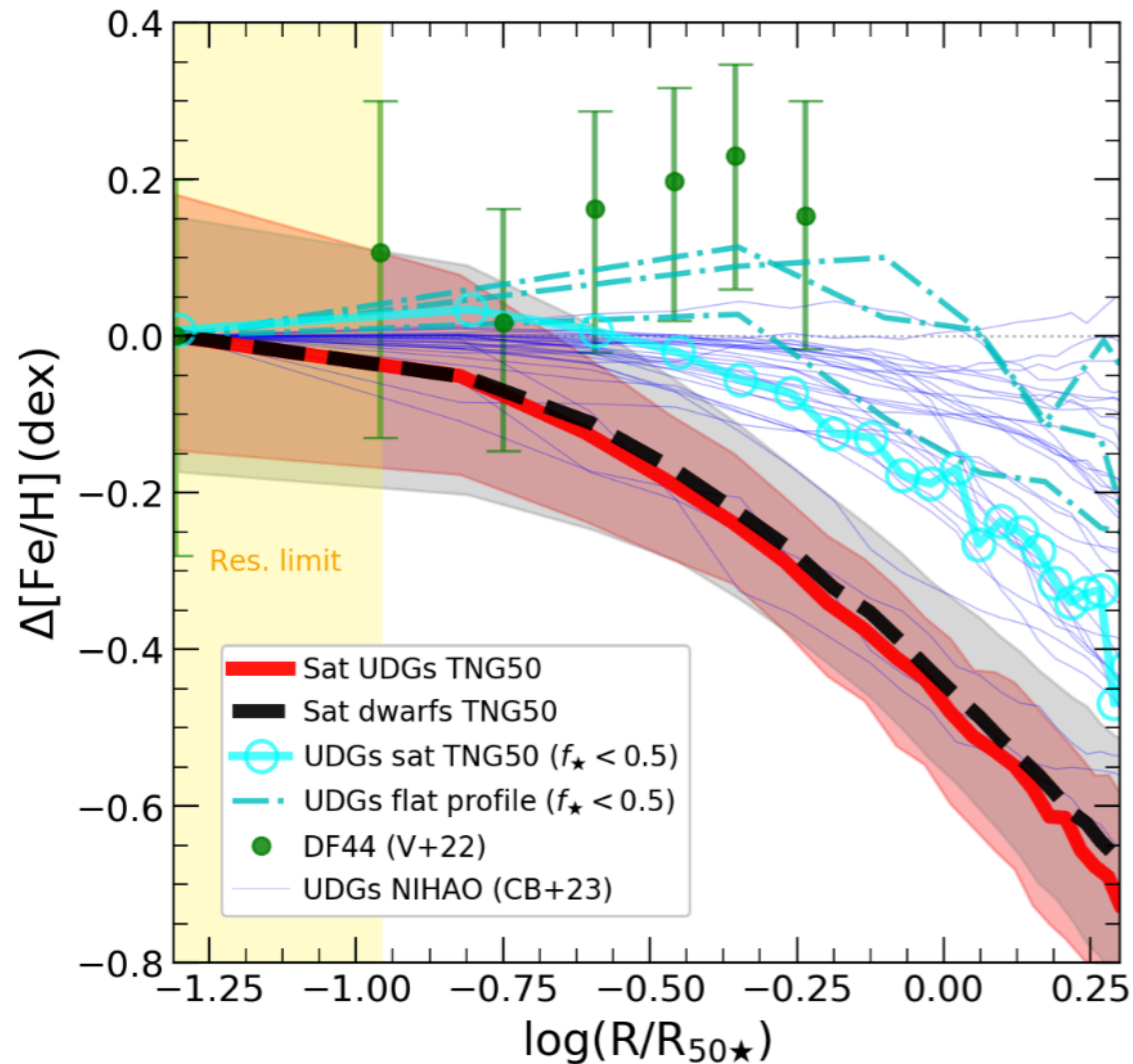
How do UDGs form?



UDGs occupy high-spin halos in TNG50

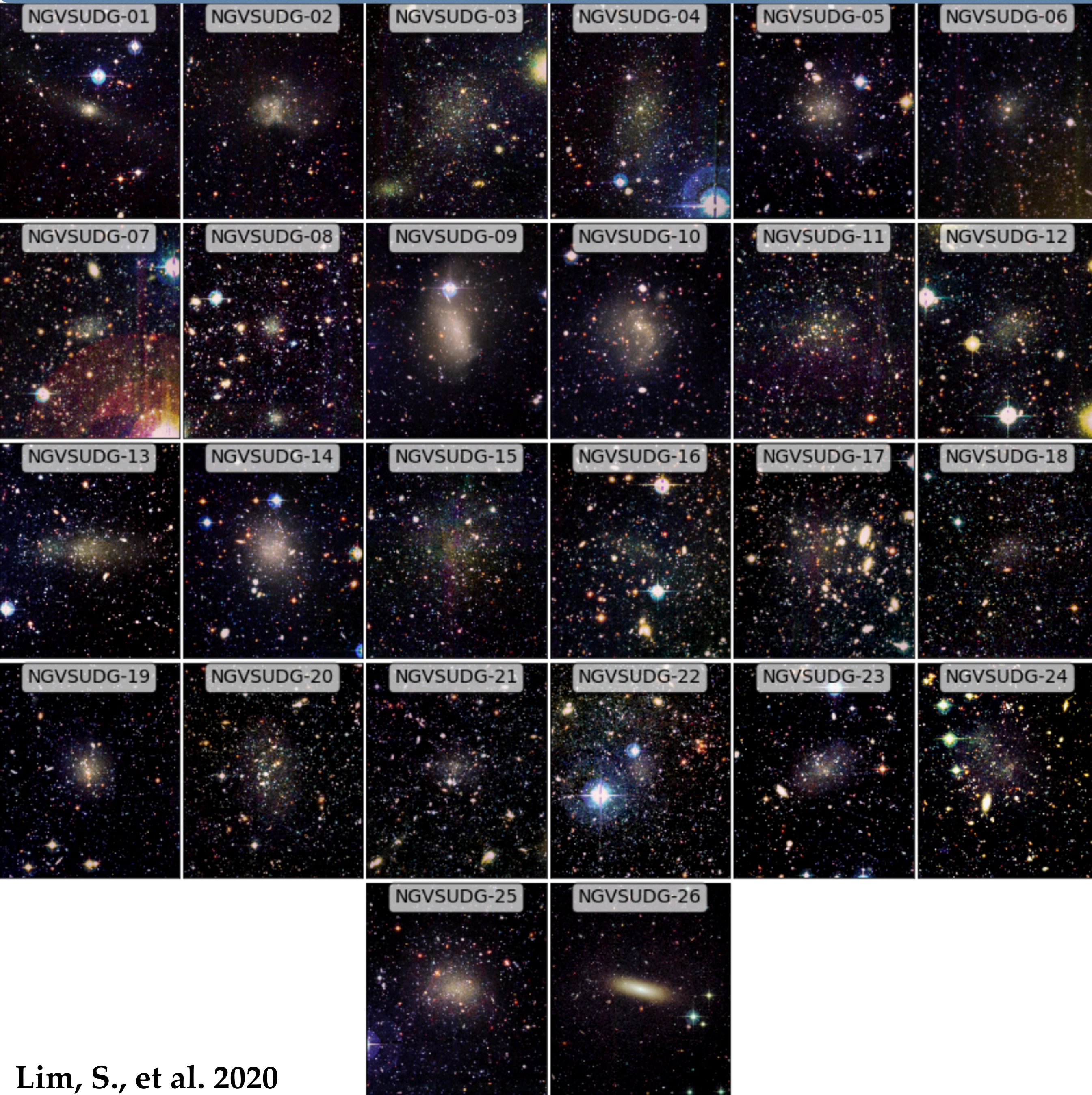
**UDGs occupy dwarf-mass halos,
 $M_{200} \sim [10^{10}-10^{11}]M_{\text{sun}}$**

Metallicity can help unravel the formation mechanism of UDGs



UDGs in TNG50 formed in high-spin halos have a steeper metallicity profile than UDGs in NIHAO simulations, formed by bursty feedback

What do we know about the dark
matter mass of UDGs?

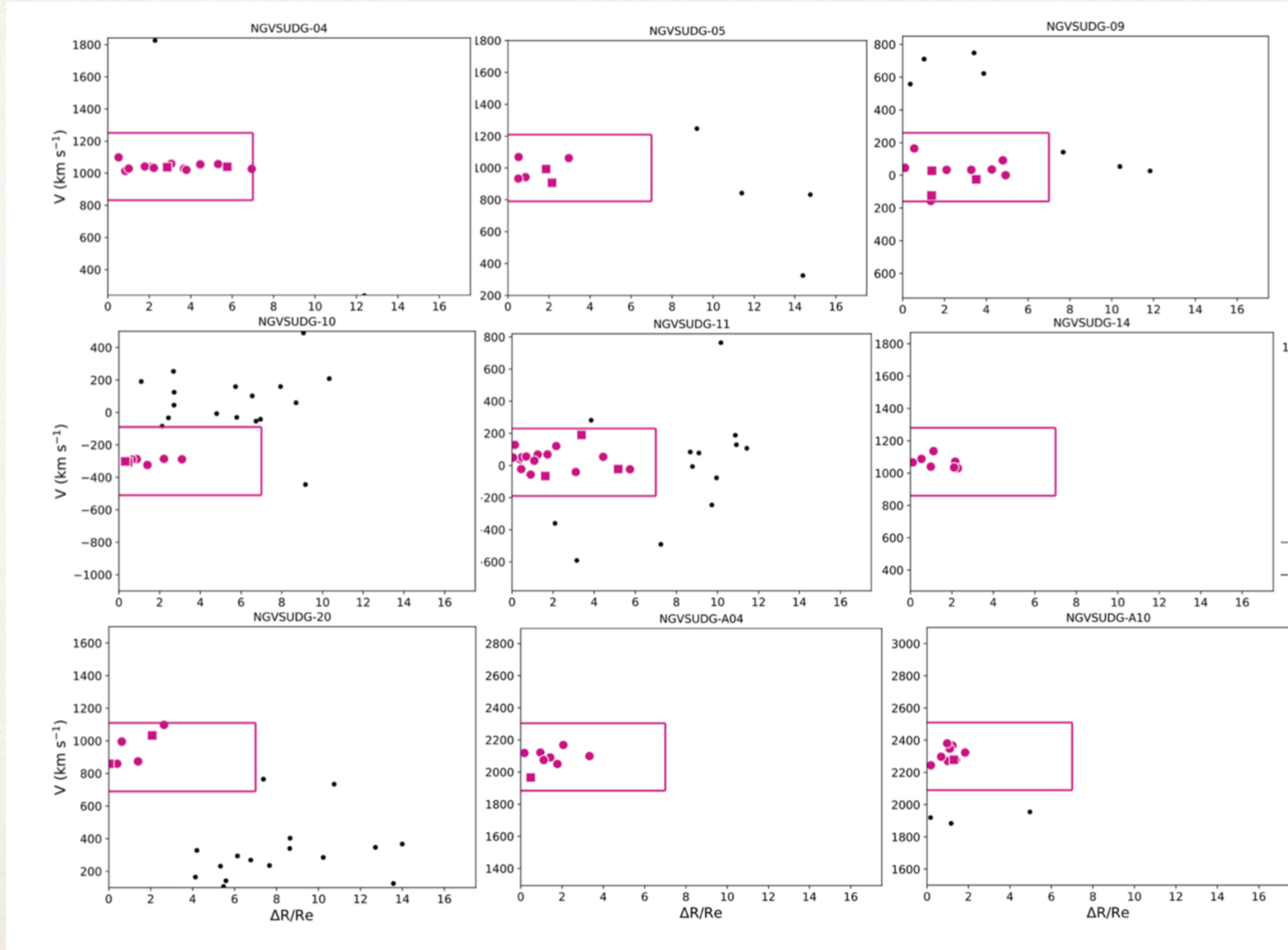


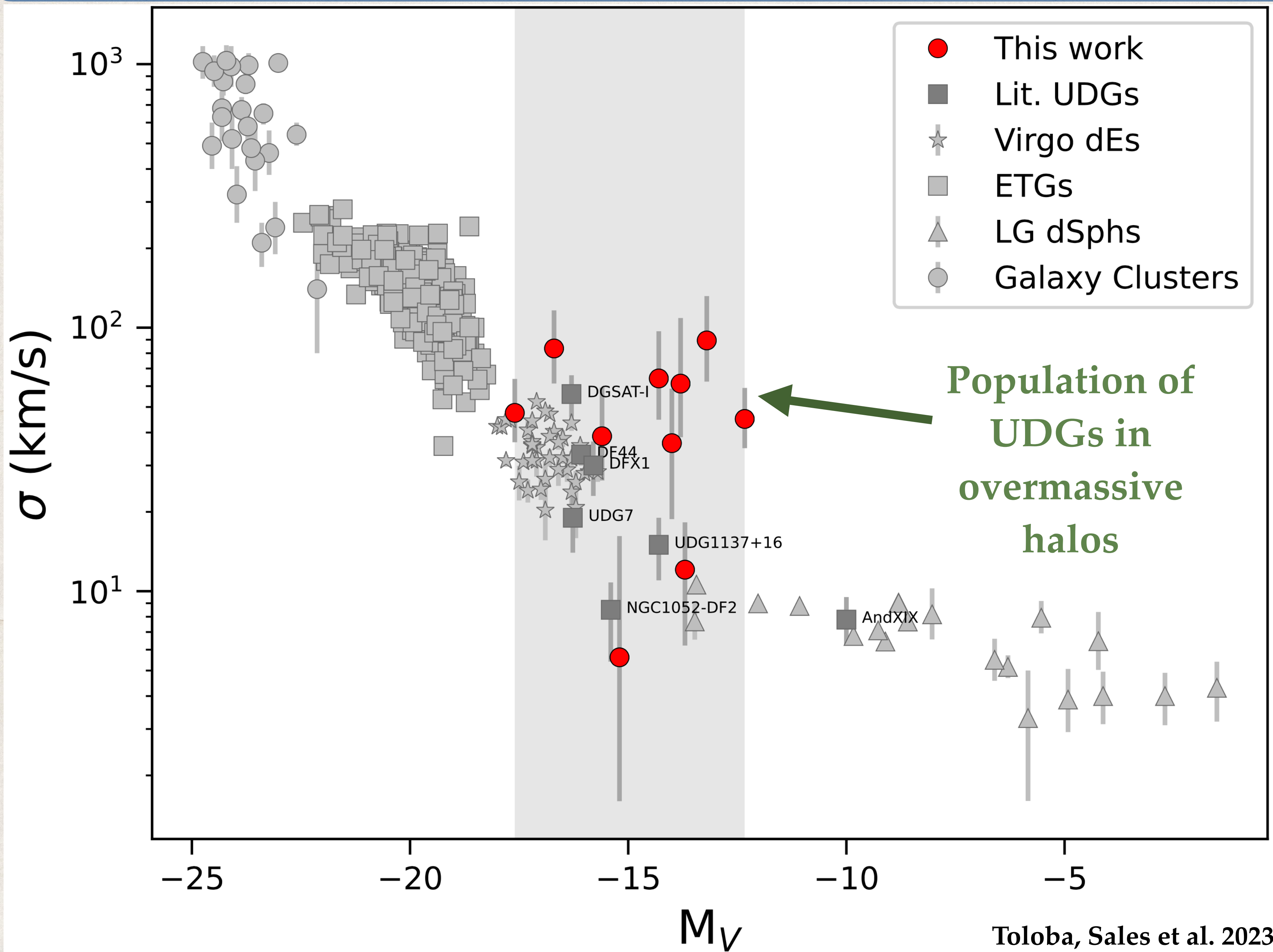
For such faint, gas-poor dwarfs, globular clusters are the best kinematical tracers

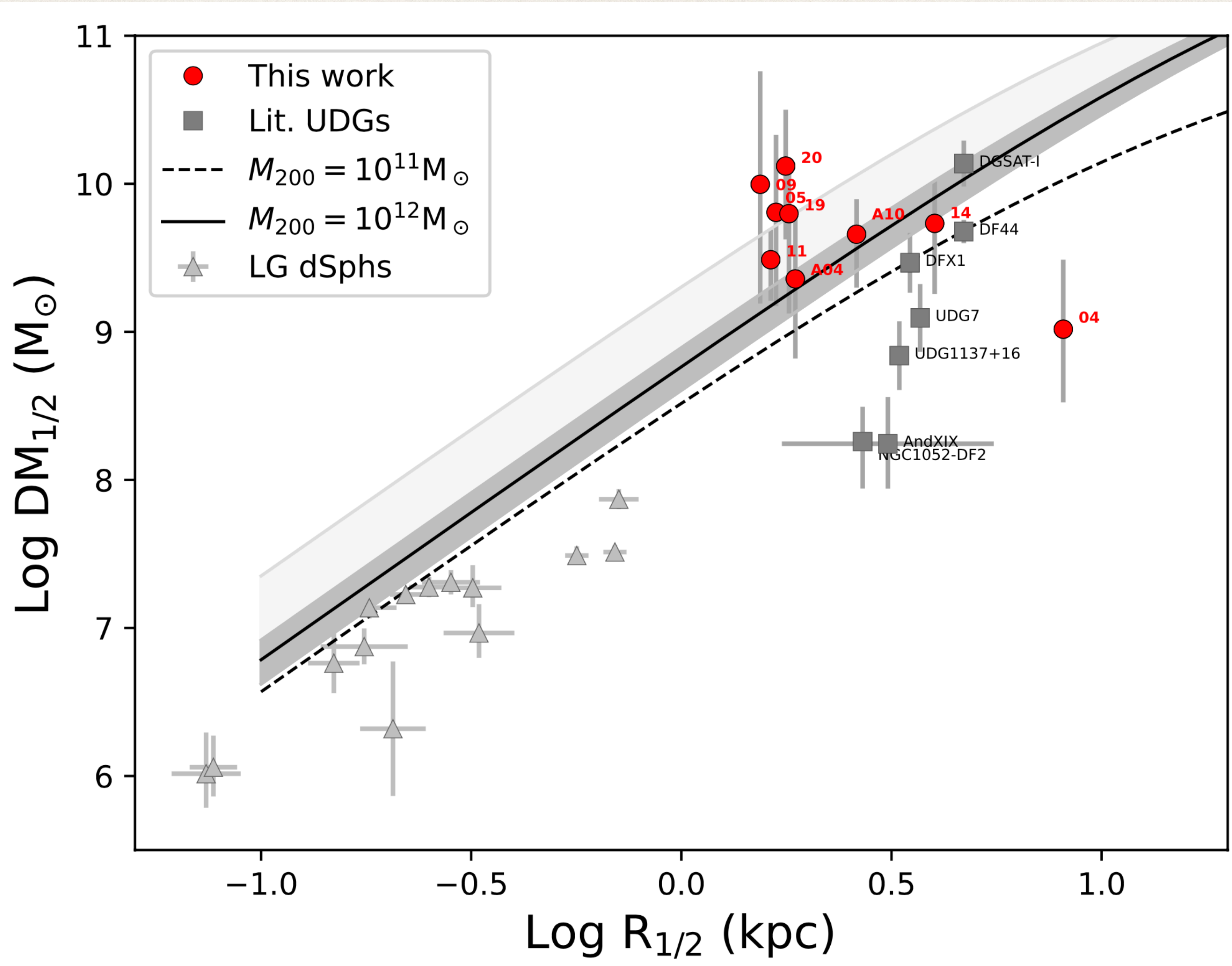
The Virgo cluster is an ideal laboratory (distance ~ 16.5 Mpc)

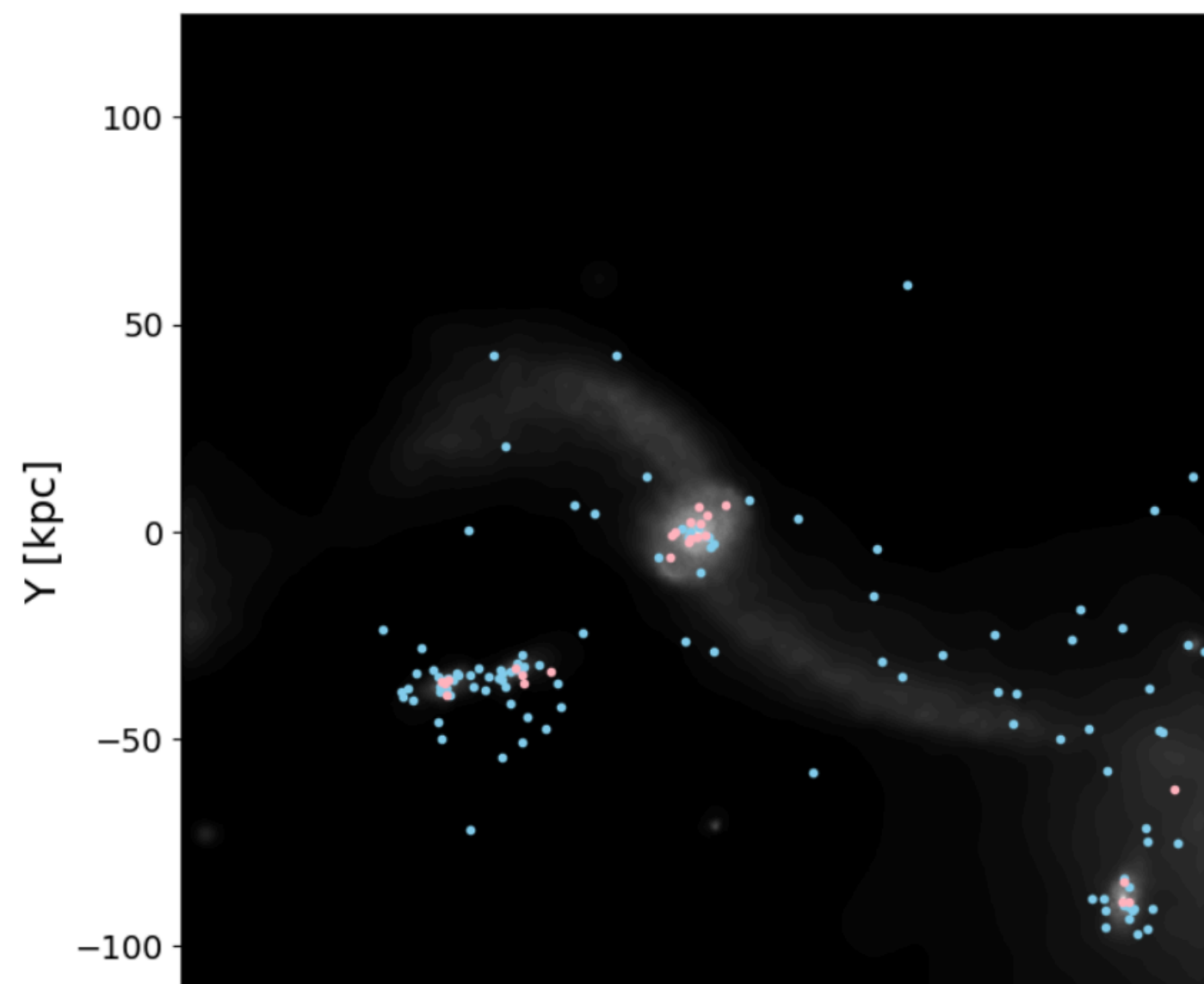
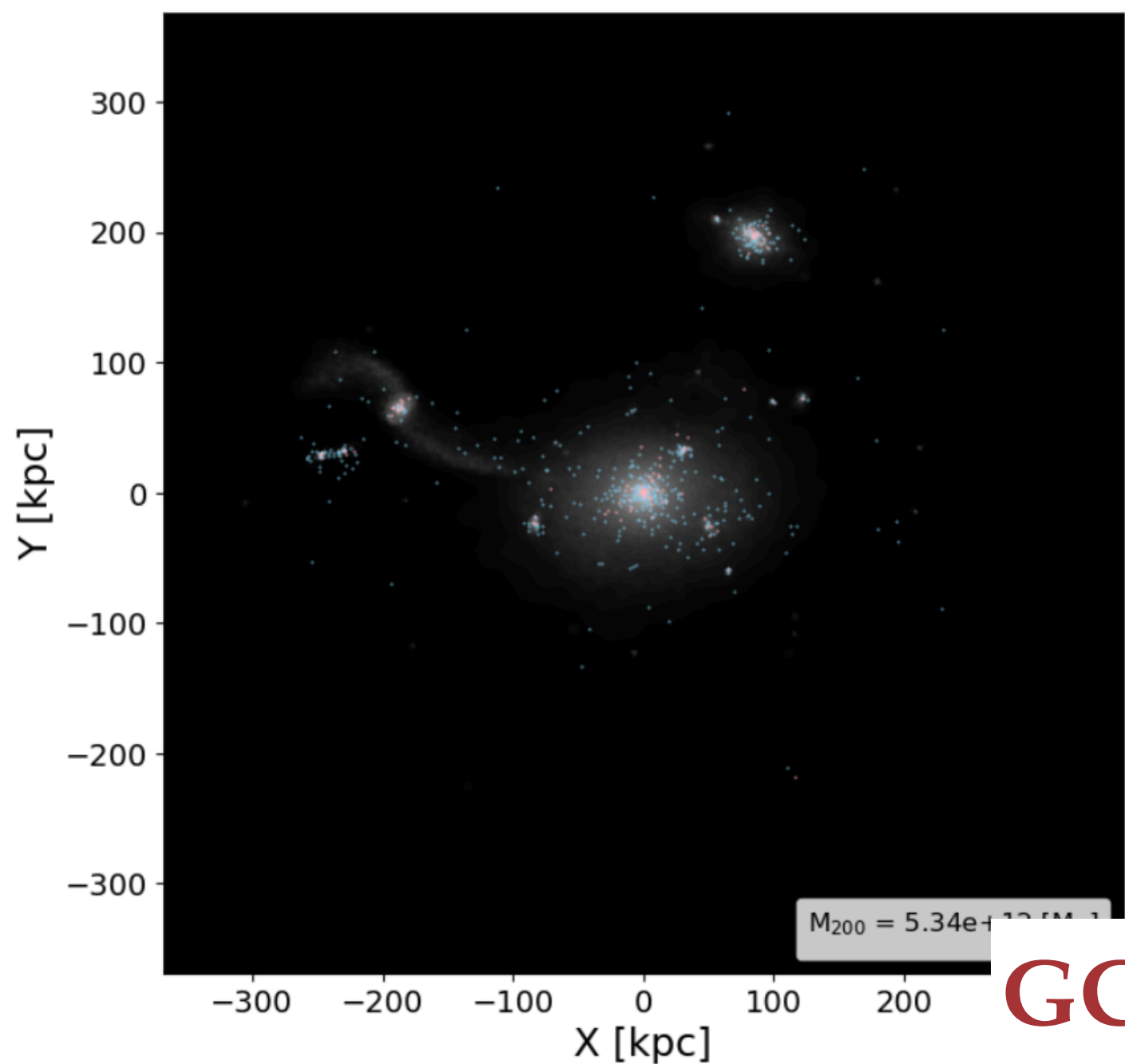
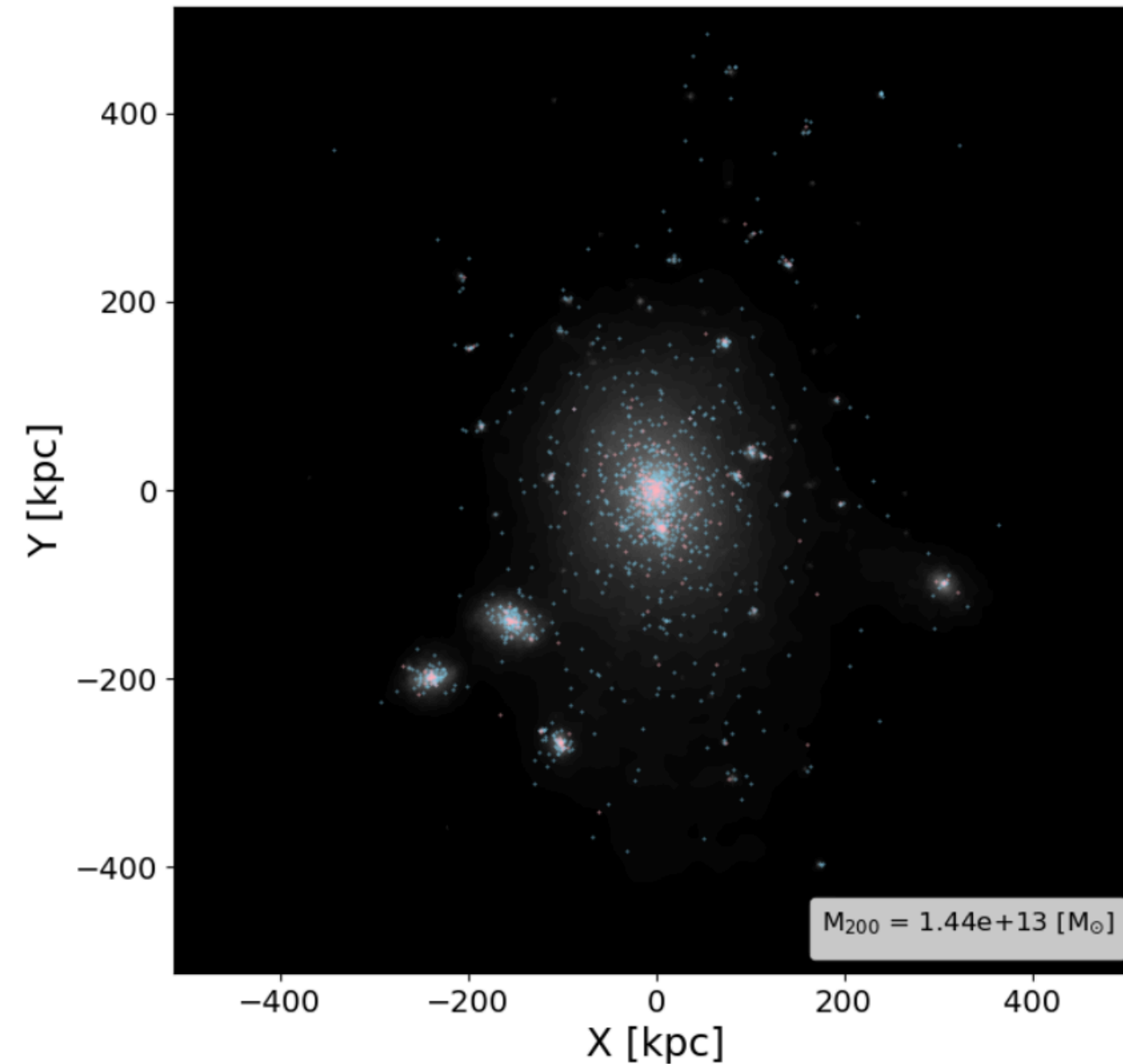
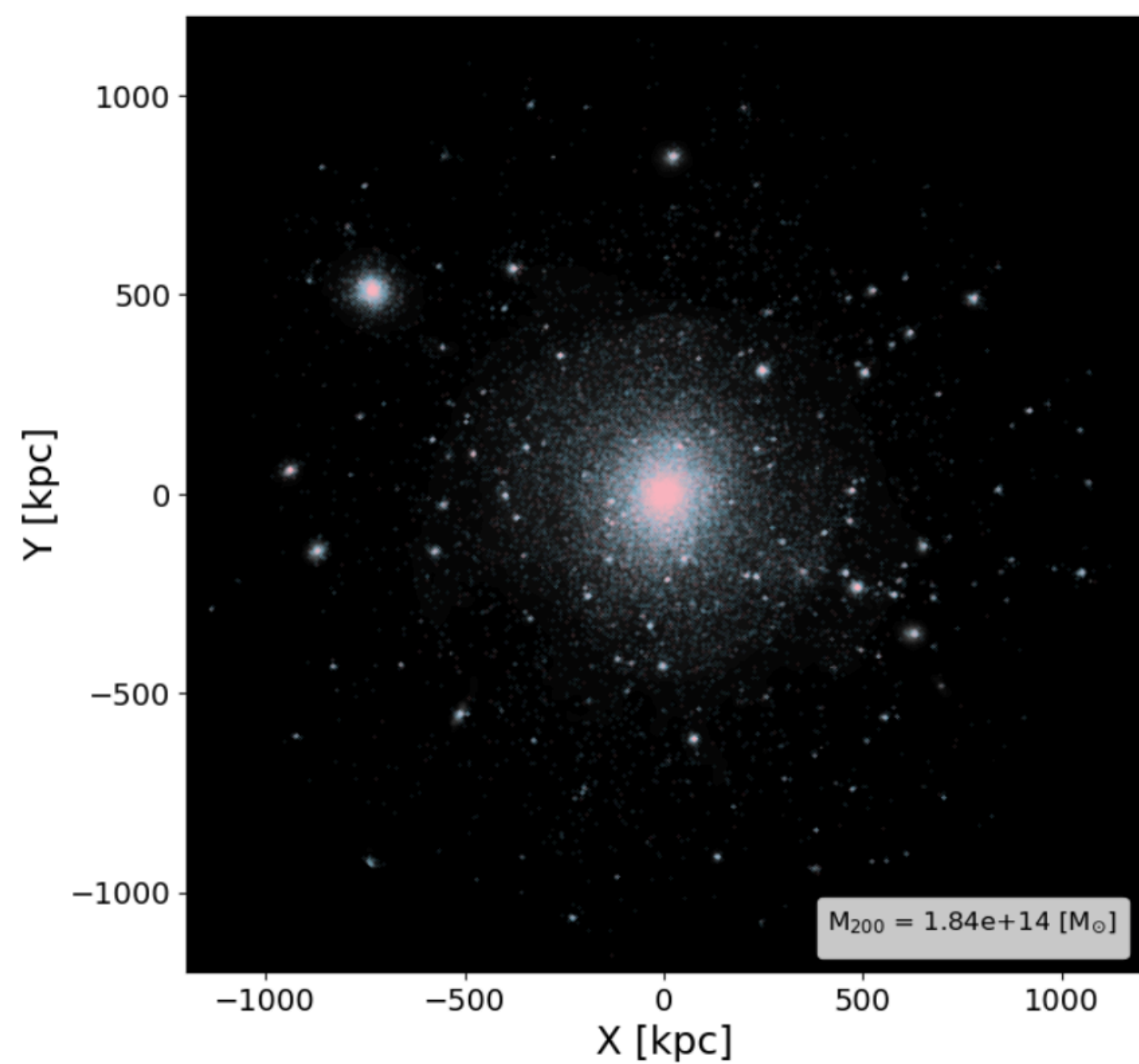
We selected from this sample all of those with $N_{GC} > 10$ to observe with Keck/DEIMOS

Identifying member GCs in UDGs





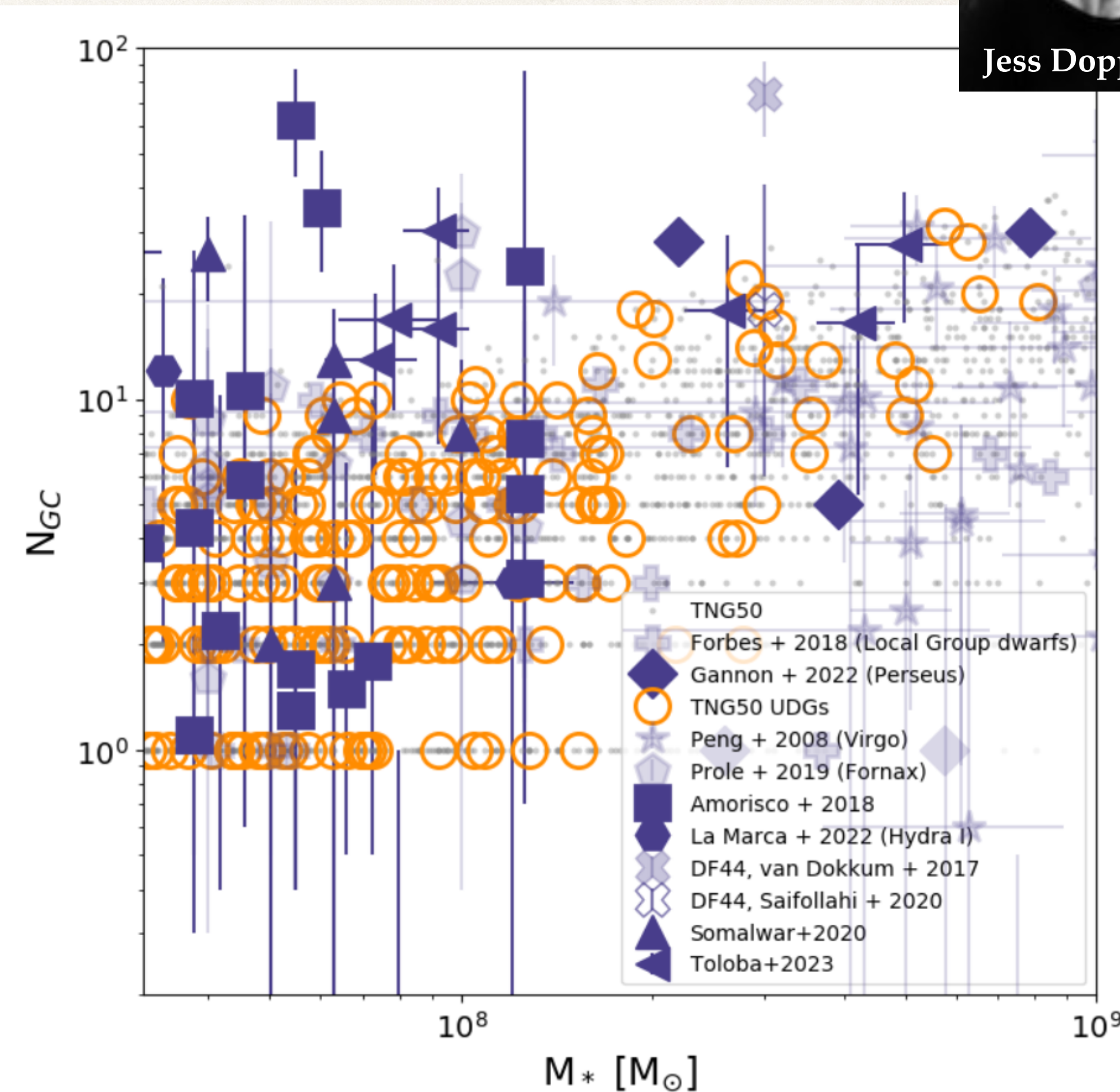




Adding GCs to groups and clusters in TNG50



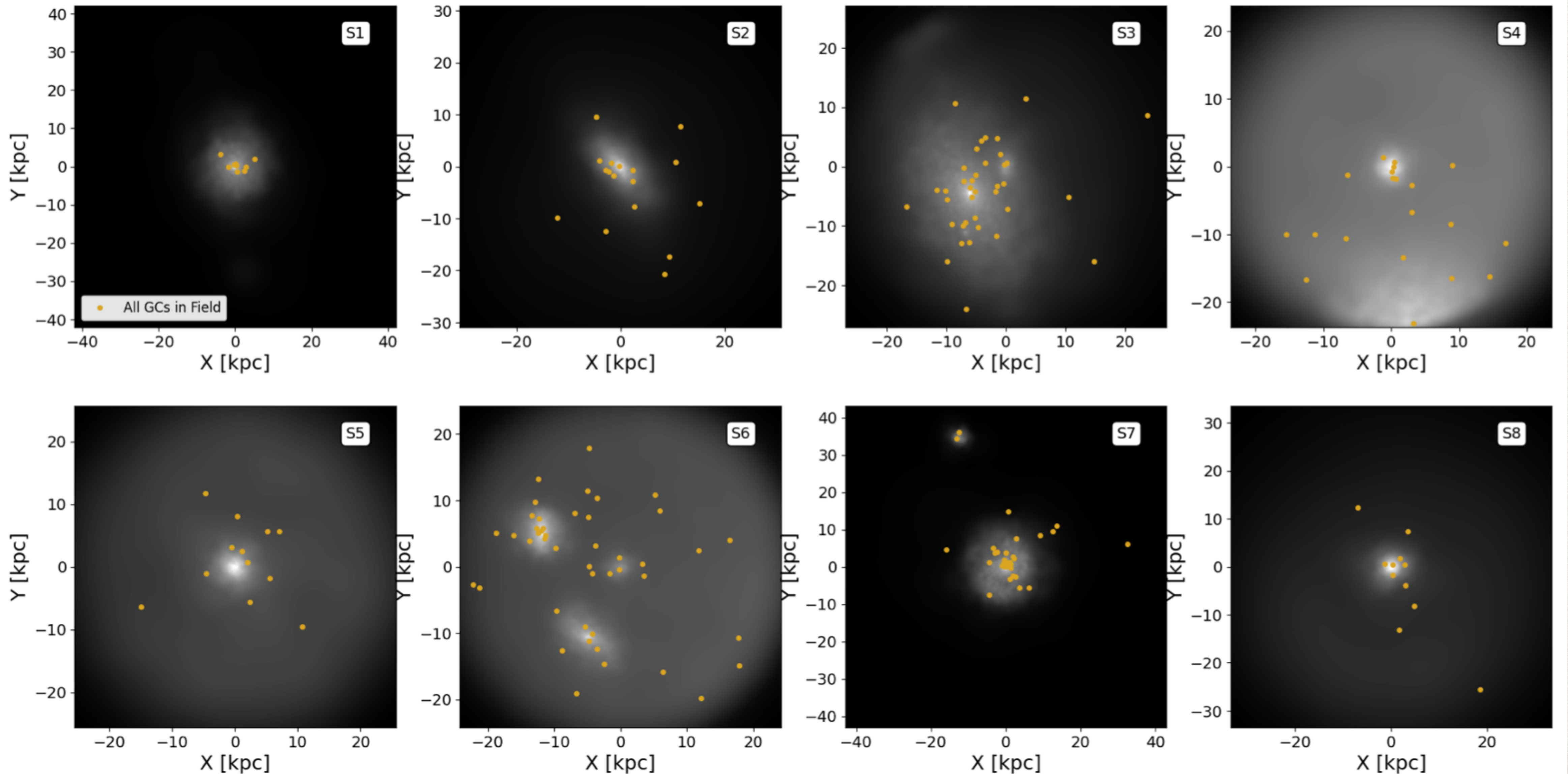
Jess Doppel



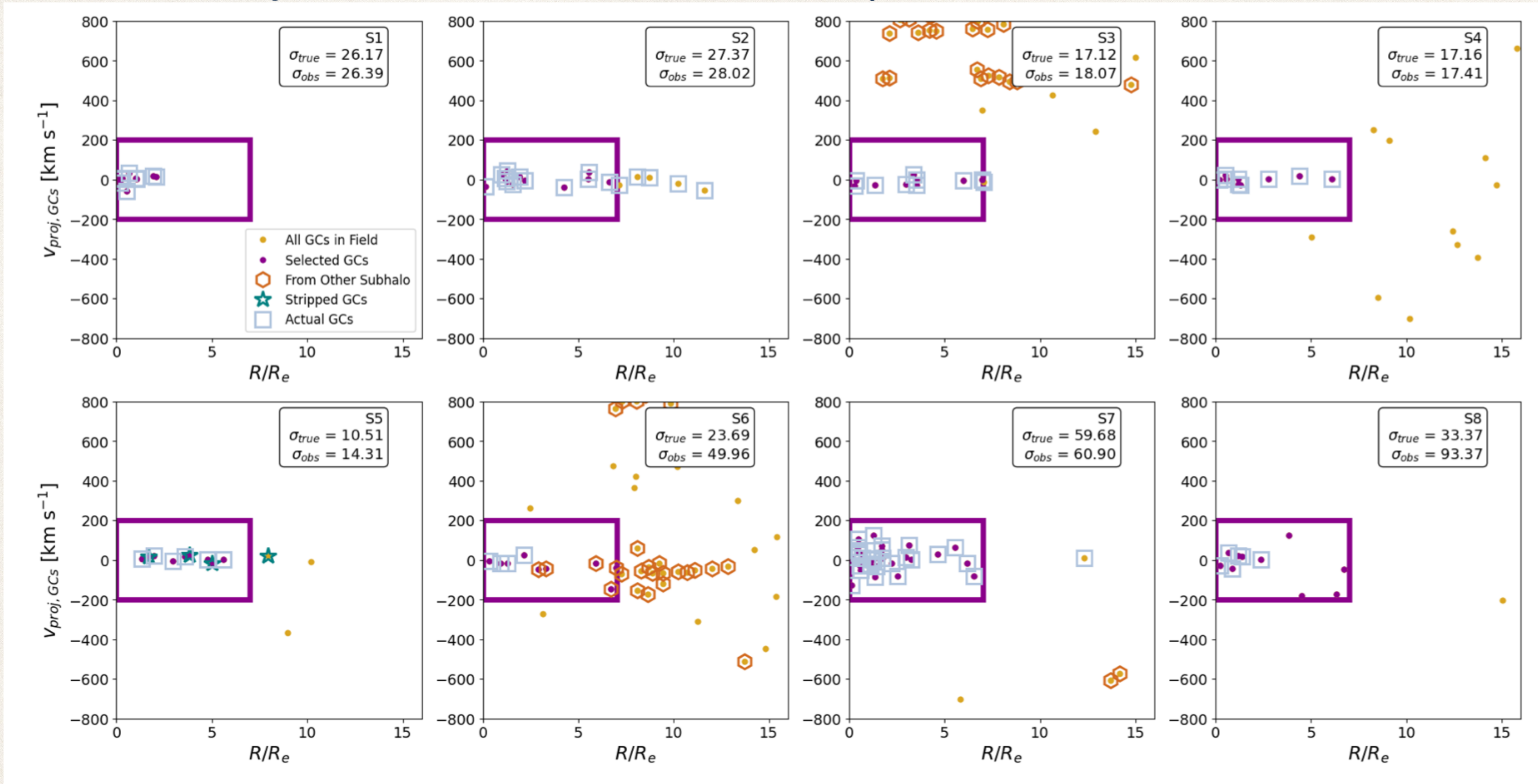
GC catalog is publicly available in the TNG database

Could large masses in UDGs be driven by intra-cluster GC contaminants?

Example simulated UDGs + GCs



Could large masses in UDGs be driven by intra-cluster GC contaminants?



Doppel, Sales et al., 2023b

While contamination can exist, not enough to explain the high-frequency of cases in Virgo
 Stellar kinematics would be good to confirm, but UDGs have very low surf. brightnesses...

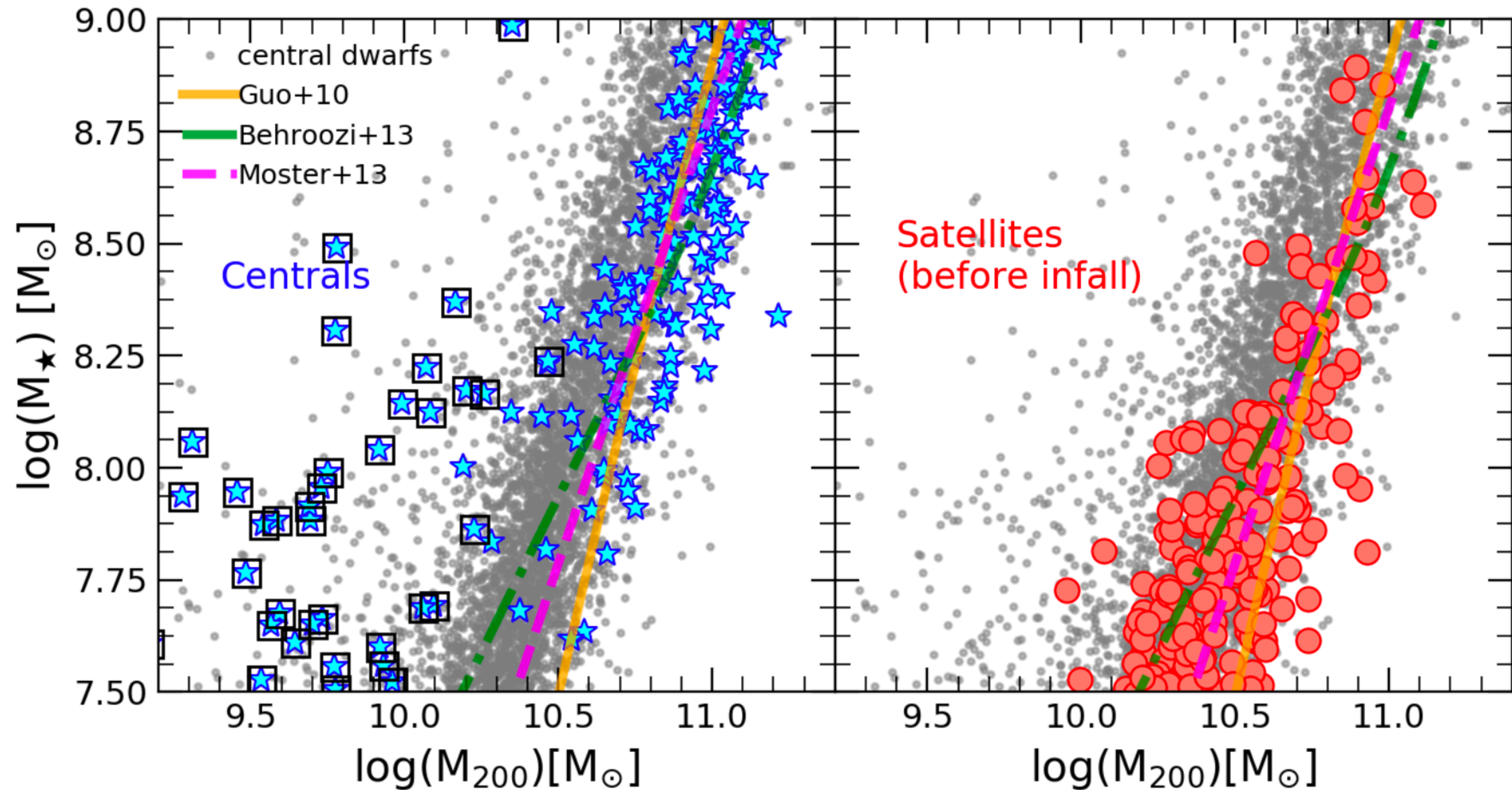
Are some UDGs "massive failures"?

If yes --> why aren't they formed in cosmological simulations?

Summary

- UDGs form naturally in TNG50, in both: satellite and field components. They preferentially form in dwarf-mass halos with large-spin (Benavides et al. 2023)
- We have performed the most uniform study of UDG kinematics in cluster-environments (Virgo) using Keck/DEIMOS (Toloba et al. 2023)
- UDGs suggest a wide range of inner dark matter content, in a way reminiscent of the “diversity of rotation curves problem”, but for early-type galaxies (Toloba et al. 2018; Toloba et al. 2023)
- We have included the modeling of GCs in cosmological hydrodynamical simulations to make one-to-one comparisons to observational data (Doppel, et al. 2021, 2023a,b)
- Simulated UDGs in TNG50 seem marginally consistent with the kinematics and inferred DM content of real UDGs, although the most DM-dense observed UDGs do not seem present in the simulated sample (Doppel et al 2023)

UDGs have dwarf-mass halos in TNG50



UDGs tend to have biased-high halo mass at a given M_{\star}

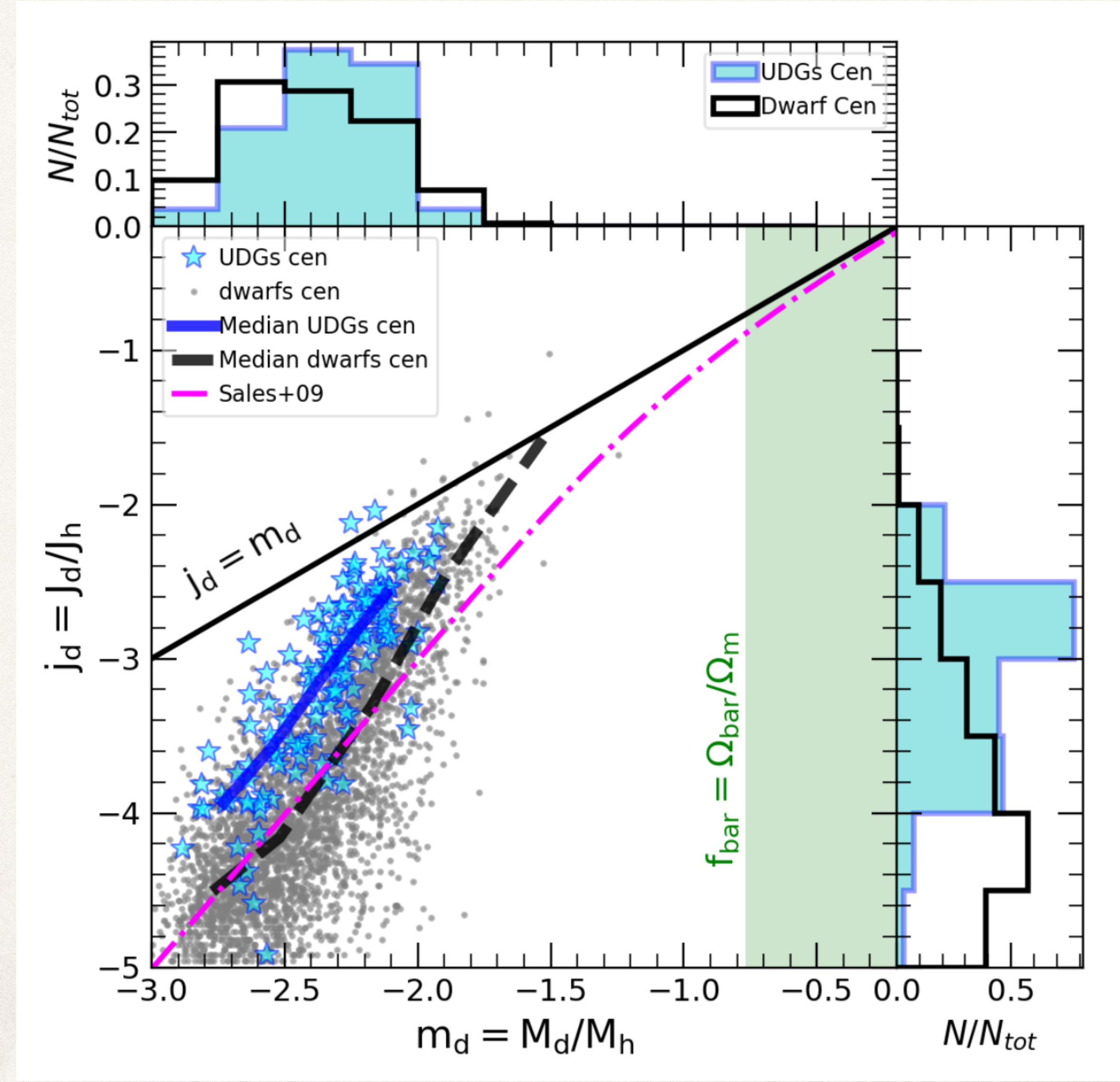
UDGs maximize the angular momentum fraction from the dark matter halo at a given disk/galaxy mass fraction

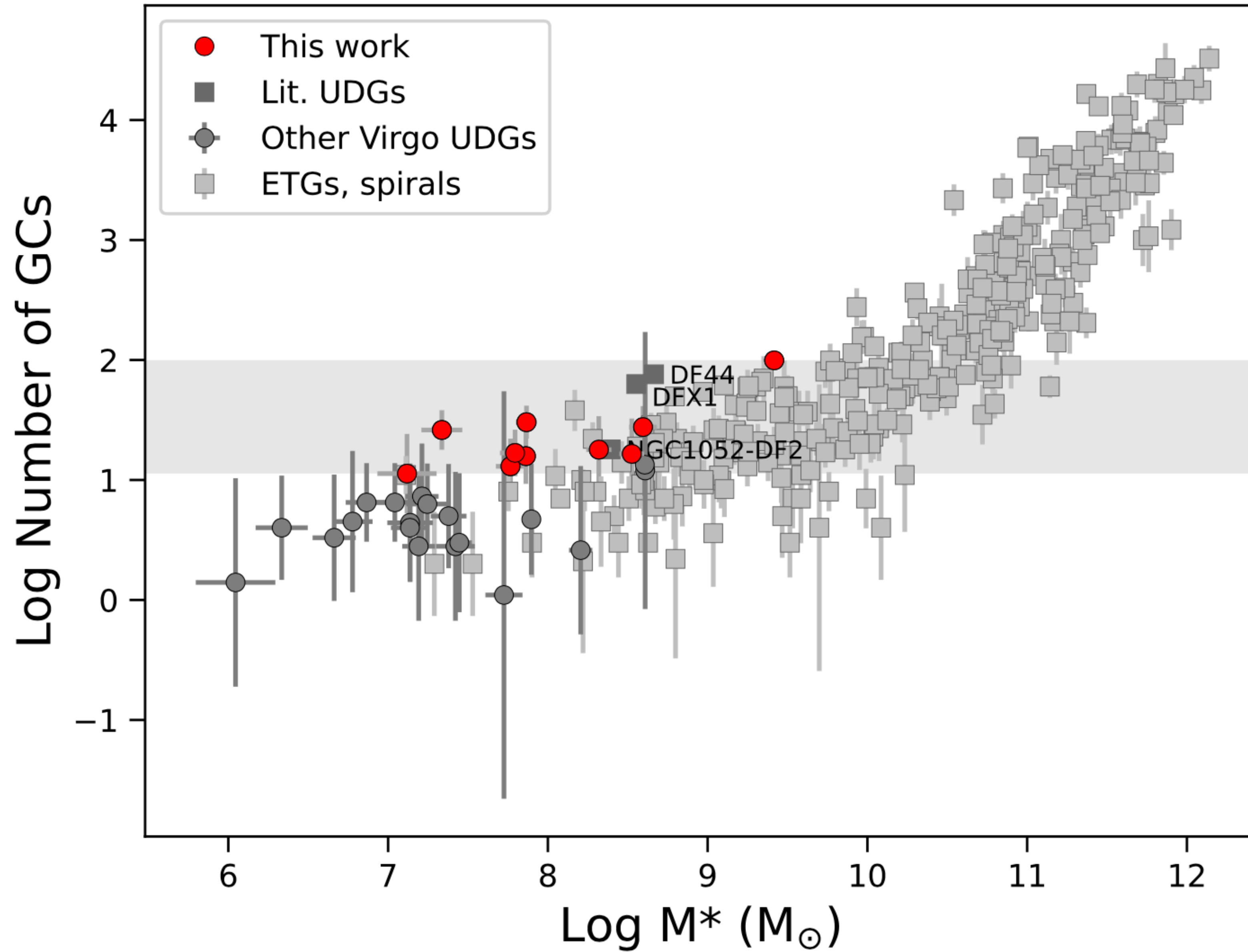
Within the Mo, Mao & White '98 formalism:

$$j_d = J_d / J_{200}$$

$$m_d = M_d / M_{200}$$

$$R_d = \frac{1}{\sqrt{2}} \left(\frac{j_d}{m_d} \right) \lambda r_{200}$$





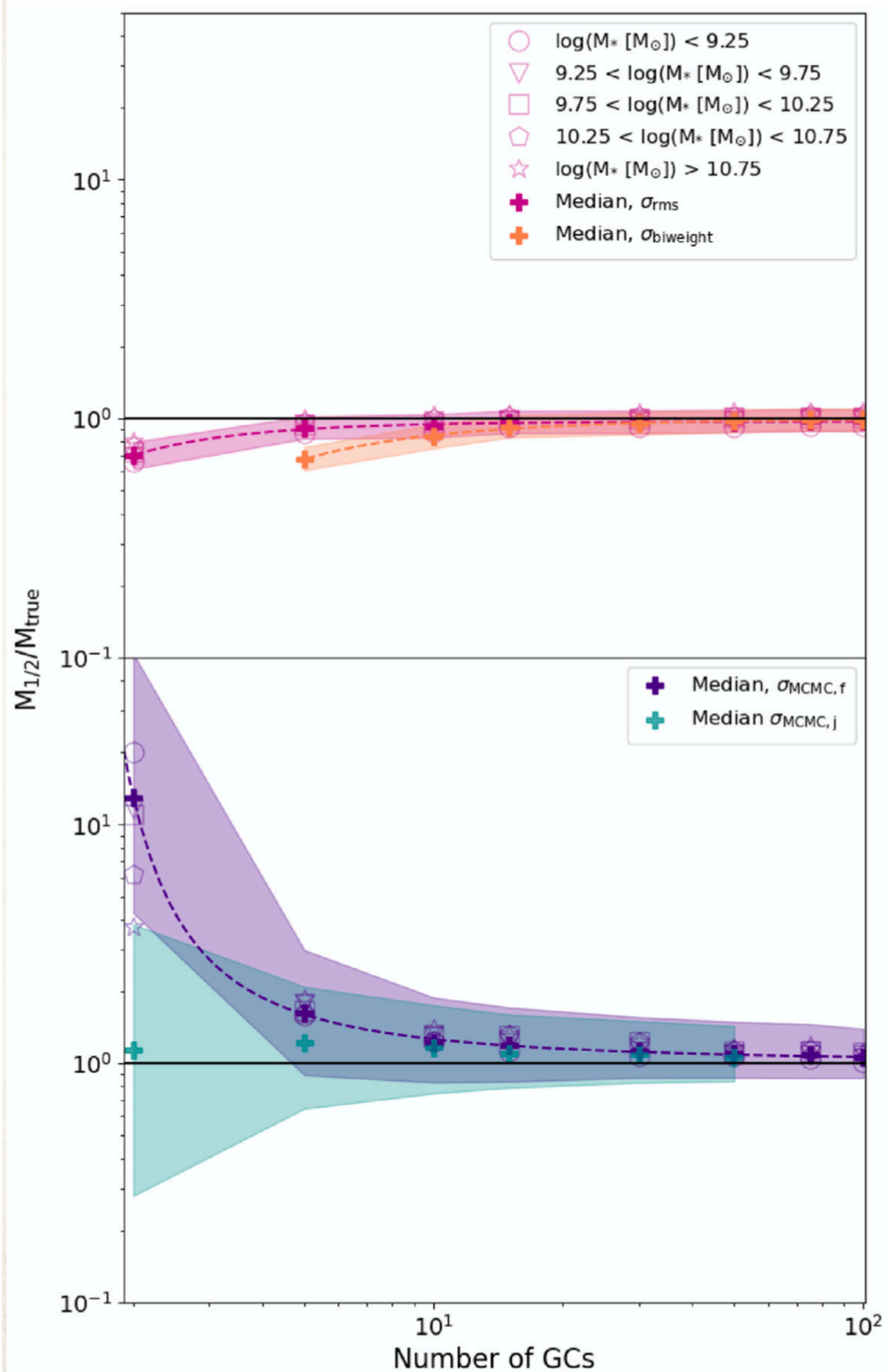
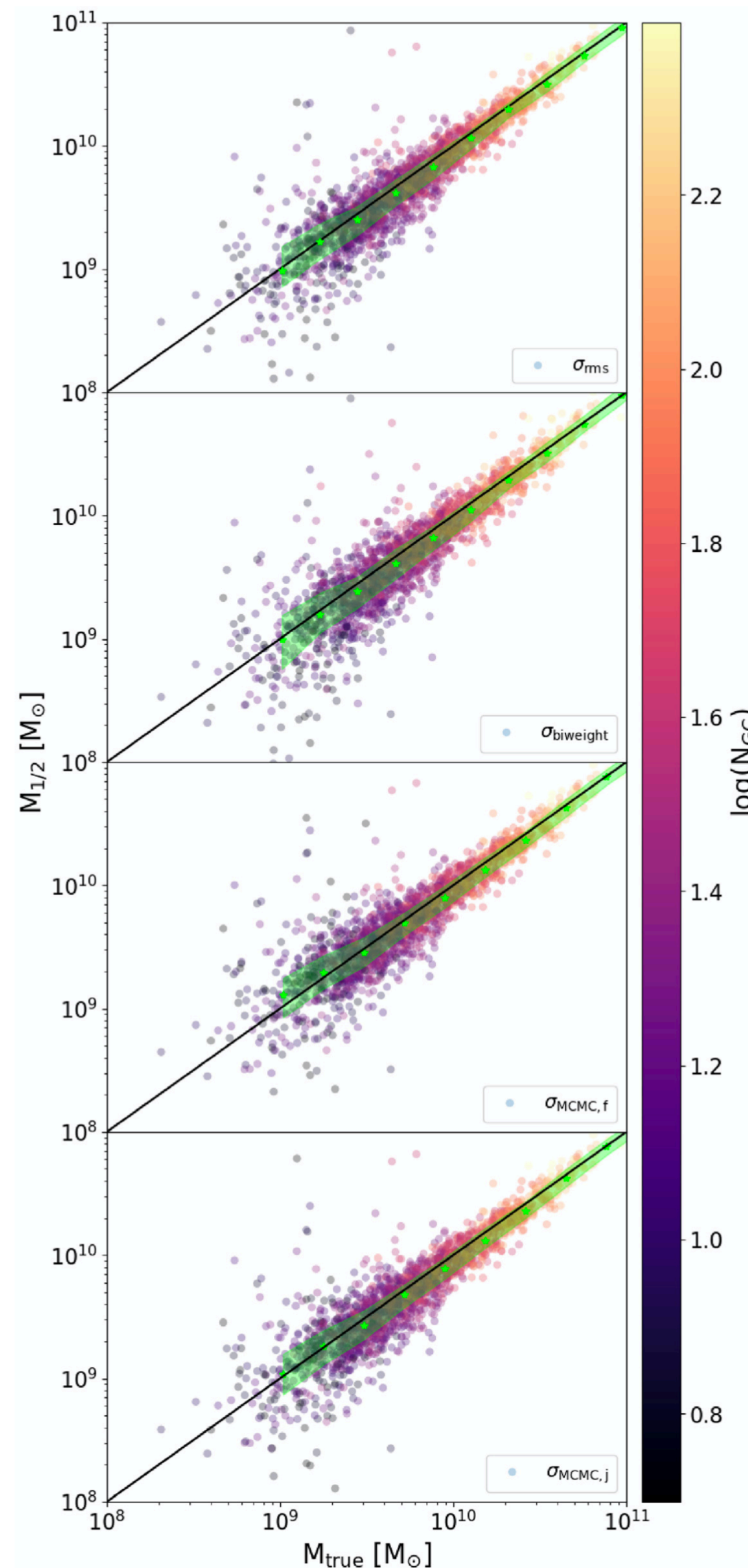
Can GCs be reliably used to measure mass in early-type dwarfs?



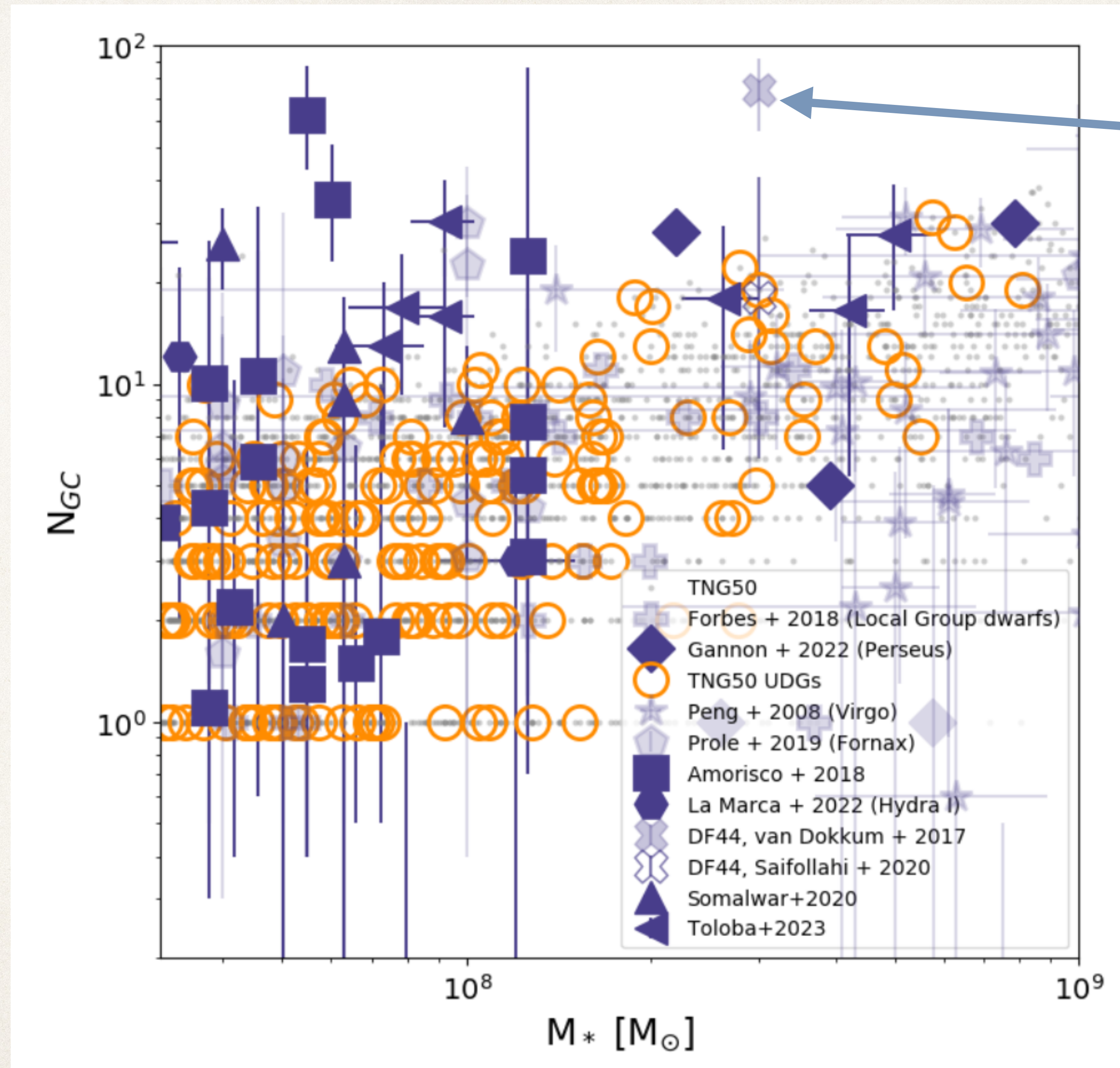
Jess Doppel

$$M_{1/2} \equiv M(r_{1/2}) \simeq 3G^{-1} \langle \sigma_{\text{los}}^2 \rangle r_{1/2}$$

→ TOTAL mass within $r_{1/2}$
↑ line-of-sight velocity dispersion
 ← radius containing half the tracer mass/light



What is the GCs content predicted for UDGs?

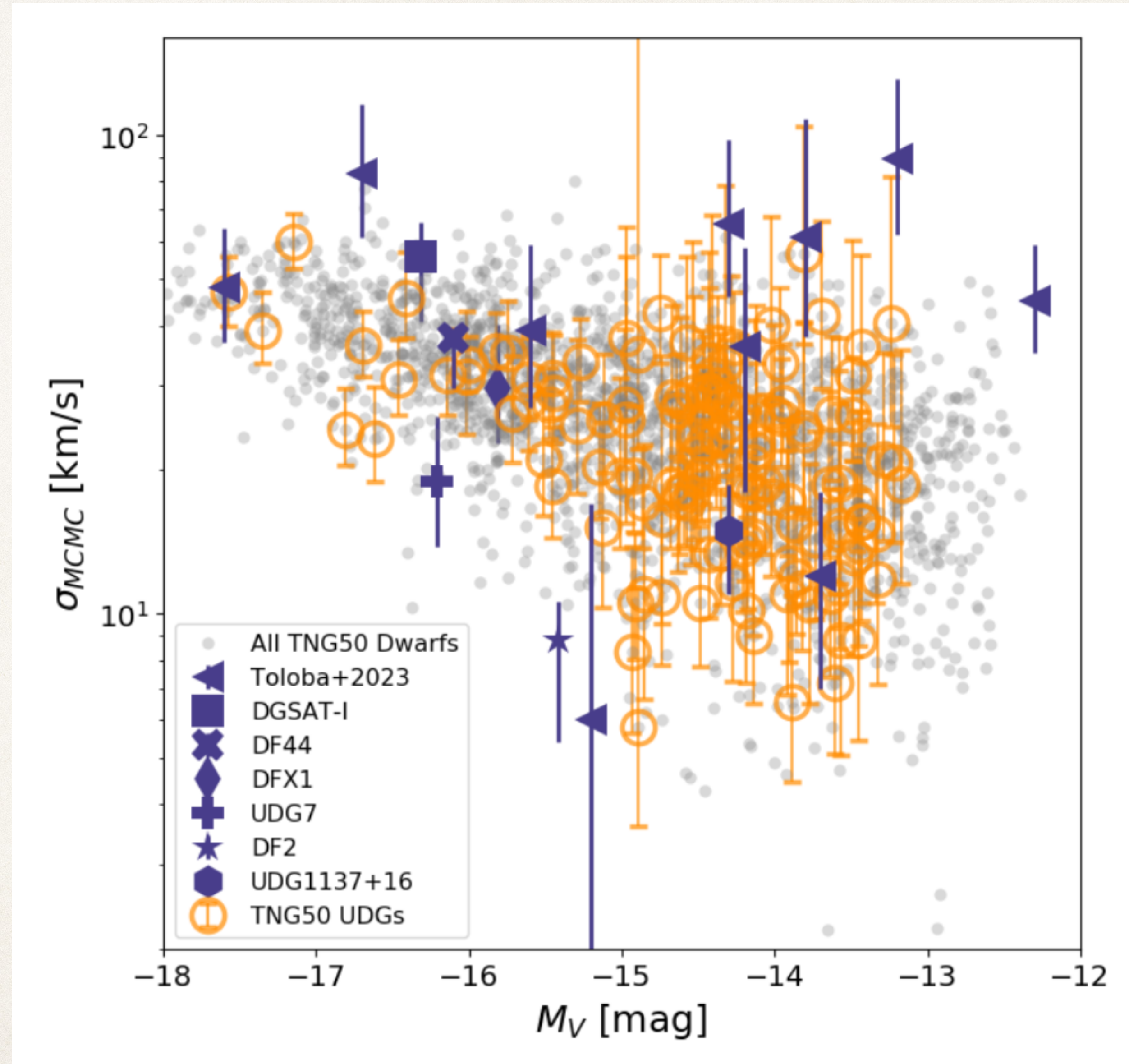


DF44 has a "revised" GC content (Saifollahi+ 2021)

Doppel, Sales et al. 2023

Simulated UDGs are consistent with observations of UDGs with dwarf-like GC content

What is the kinematic of GCs predicted for dwarfs?



Doppel, Sales et al. 2023

Simulated UDGs marginally consistent with observations, but struggle to reproduce high σ values